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# Programmable Spectral Design and the Binary Supergrating and Tubulogenesis, Cystogenesis and Polycystic Kidney Disease

The control of light on the basis of its wavelength is key to many processes in telecommunication, spectroscopy and chemical/biological sensing. Examples include wavelength-channel selection and chromatic dispersion compensation in optical communication, Hadamard and wavelength-sweep (traditional) spectroscopy, and proposed lab-on-chip microenvironments for threat sensing and biological experiments. In this talk, I present the Binary Supergrating (BSG), a novel technology that enables the programmable and near-arbitrary control of optical amplitude and phase spectra using a simple and robust structure. This guided-wave structure consists of an aperiodic sequence of binary elements, which takes the form of an elaborate barcode. The BSG's binary sequence encodes an optical program that defines device functionality, allowing the same BSG design, and even the same device – the BSG can be made reprogrammable – to perform a broad range of functions. As a digital approach to spectral engineering, the BSG presents many of the same advantages offered by the digital approach to electronic signal processing (DSP) over its analog predecessors. As such, it has potential importance for many domains of optical manipulation. This is especially the case with the BSG's reprogrammable form, which stands as a universal wavelength processor.

In the second part of my talk, I discuss my current work on the mechanisms of polycystic kidney disease (PKD), the world's most prevalent life-threatening genetic disorder. It is estimated that there are between 7 and 12.5 million individuals in the world living with PKD, a disease that is blind to ethnicity, gender or socioeconomics. At this date, PKD has no cure or specific treatment, and very little is known about its workings. PKD's most characteristic symptom, from which it gets its name, is the development of a large number of cysts from the tubules comprising the kidneys. It is believed that the disease is caused by a failure in the morphogenic mechanisms that create and maintain the tubule form. However, careful studies of the diseased biomolecular pathways have hitherto been difficult due to the absence of a reproducible three-dimensional *in vitro* model system. Here, I present a promising new model system for PKD that is based on the adaptation of semiconductor microfabrication techniques to the patterning of extracellular matrix (ECM) protein hydrogels such as collagen I gel or Matrigel. Such a system allows the pre-forming of renal tubules in defined patterns while enabling the tissue to restructure as dictated by its internal programming, healthy or sick. Furthermore, novel protocols for seeding the gel can simulate the presumed "two-hit" nature of *in vivo* autosomal-dominant PKD in an unprecedented manner.